Monitoring of water levels and flood discharge

Changes Workshop TS-02
&
11th edition International Summer School
Environmental Hazards & Sustainable Development
in Mountain Regions

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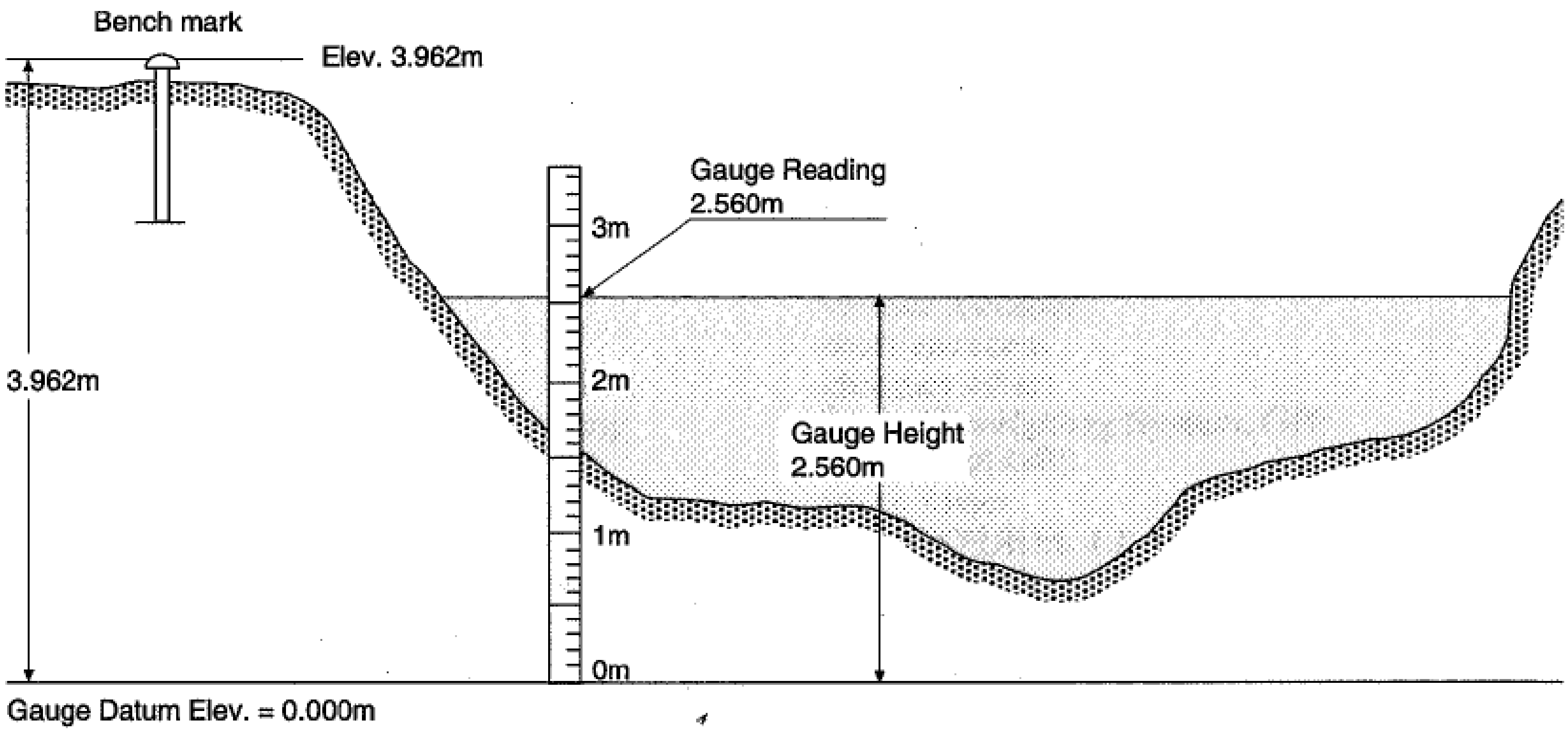
Content

1. Monitoring water levels
2. Transforming to discharge/flood
3. How to estimate extreme flood discharge?
4. Streamflow monitoring network guidelines

Objective

To discuss stream monitoring methods, also during or after extreme discharge events and to give the WMO guidelines for a monitoring network.

The principle of a gauging station



W. Boiten (2008): Hydrometry, 3rd Edition Unesco-IHE lecture note series

Why are we measuring water levels?

- Navigation
- Flood protection
- Discharge (-> rating curves)
- Hydrographs (-> duration curves)
- Water balance

THE 5 ESSENTIAL ELEMENTS OF A HYDROLOGICAL MONITORING PROGRAM

1. Quality Management System
2. Network Design
3. Technology
4. Training
5. Data Management

Whitepaper, Aquatic Informatics

Quality Management System

Quality objective

- **USGS techniques and Standards**
- **USGS Techniques of Water resources Investigations**
- **ISO Technical Committee 113**
- **WMO operational Hydrology report**

Service Objectives

- **Staff**
- **Equipment and life cycle management**
- **QC, metadata**

Network design

- **WMO guideline**
- **Evaluation of the network,**

  ->> can only be done after the first data are collected

Hydrometeorological network design

DEFINITIONS

A network is an organized system for the collection of information of a specific kind. Its component parts must be related to one another; that is. Each station, point, or region of observations must fill one or more definite purpose in either space or time. (Langbein, 1965)

A hydrological-data network is a group of data-collection activities that are designed and operated to address a single objective or a set of compatible objectives. (WMO Guide, 1994)

Type of measurement and design of network are function of what is being measured and for what reason

Design of hydrometric networks

Types of stations making up a network :

- Main gauges, primary gauges

  Permanent stations and continuously and correctly monitored. These are reference stations for statistical analysis

- Secondary gauges

  Maintained for a limited number of years but sufficient in order to establish good correlation with data at main stations

- Special gauges, project gauges

  Based on specific needs : irrigation, navigation, flood forecasting, dams management, …

Hydrometeorological network design

VALUE and COSTS

- To have a value data must be used and have influence on decision
- Increased (use of) data leads to more reliable planning
- In case of data shortage over-design to reduce uncertainty is expensive
- In case of data shortage, a too fast failure of a structure is expensive
- Operational management improves having more historical and real-time data

Data cost money -> has to be paid, or by society (government) or by users

WMO guidelines for streamflow monitoring

1) Nature

- Streamflow is an integrated, lumped response of whole basin to input
- Totally different then P or E

2) Network considerations

Type of station

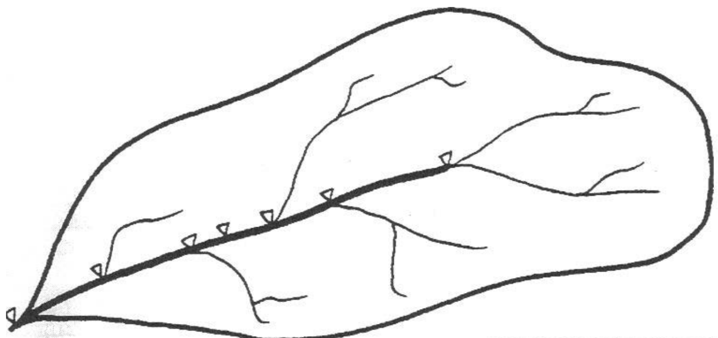
- Basic (long-term for trends and river monitoring…)
- Secondary (short-term, regional investigations…)
- Survey (interpolation, flood crests, cheap, …)

WMO guidelines for streamflow monitoring

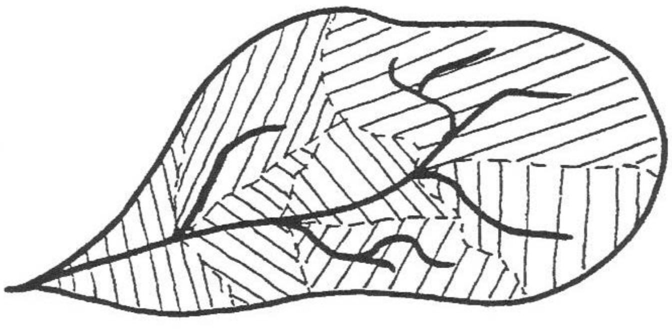
1) **Nature**
2) **Network considerations**

Bases for network design

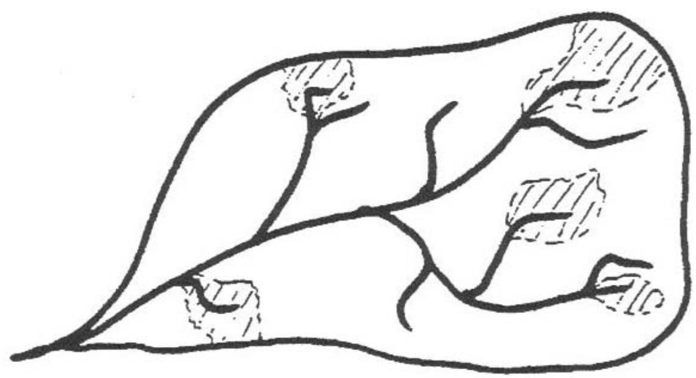
- Linear distribution - Large rivers
- Territorial distribution - Medium sized rivers, areal distributions
- Sampling - Small representative basins



LINEAR DISTRIBUTION



TERRITORIAL DISTRIBUTION



SAMPLING

WMO guidelines for streamflow monitoring

1) Nature
2) Network considerations
3) **Density guidelines**

WMO, 1994

Physiographic Units	Minimal Density per station *area in km² per station*
Costal zones	2750
Montaneaous zones	1000
Interior plains	1875
Hilly Regions	1875
Small islands	300
Polar and arid zones	20 000

WMO guidelines for streamflow monitoring

1) Nature
2) Network considerations
3) Density guidelines
4) Network tests
5) **Locations**
    - Is very much function of basin size and physiography (hydrotope maps…)
6) **Temporal aspects**
    1) It is difficult to measure discharge directly
    2) We must measure continuously or at pre-defined intervals e.g. 5 minutes, 15 minutes, 1 hours, …
    3) Long-term monitoring necessary to derived long-term fluctuations, e.g. land use change effects, climate change effects, …

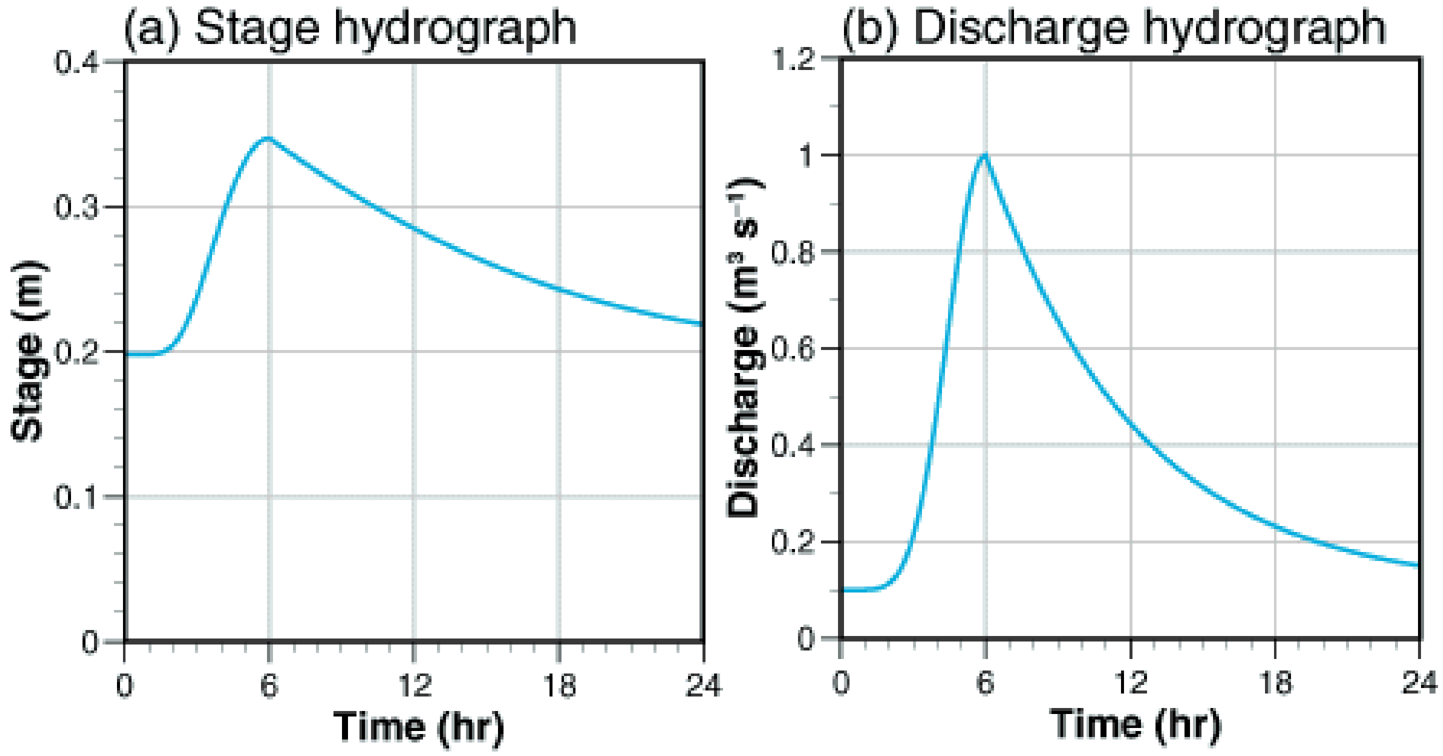
Training

No data and equipment without people being able to use it and operate it

Data management

- **Real time data and automation**
- **Credible rating curves**
- **Data visualization, correction and markup**
- **Reporting and publication**

Application of rating curve

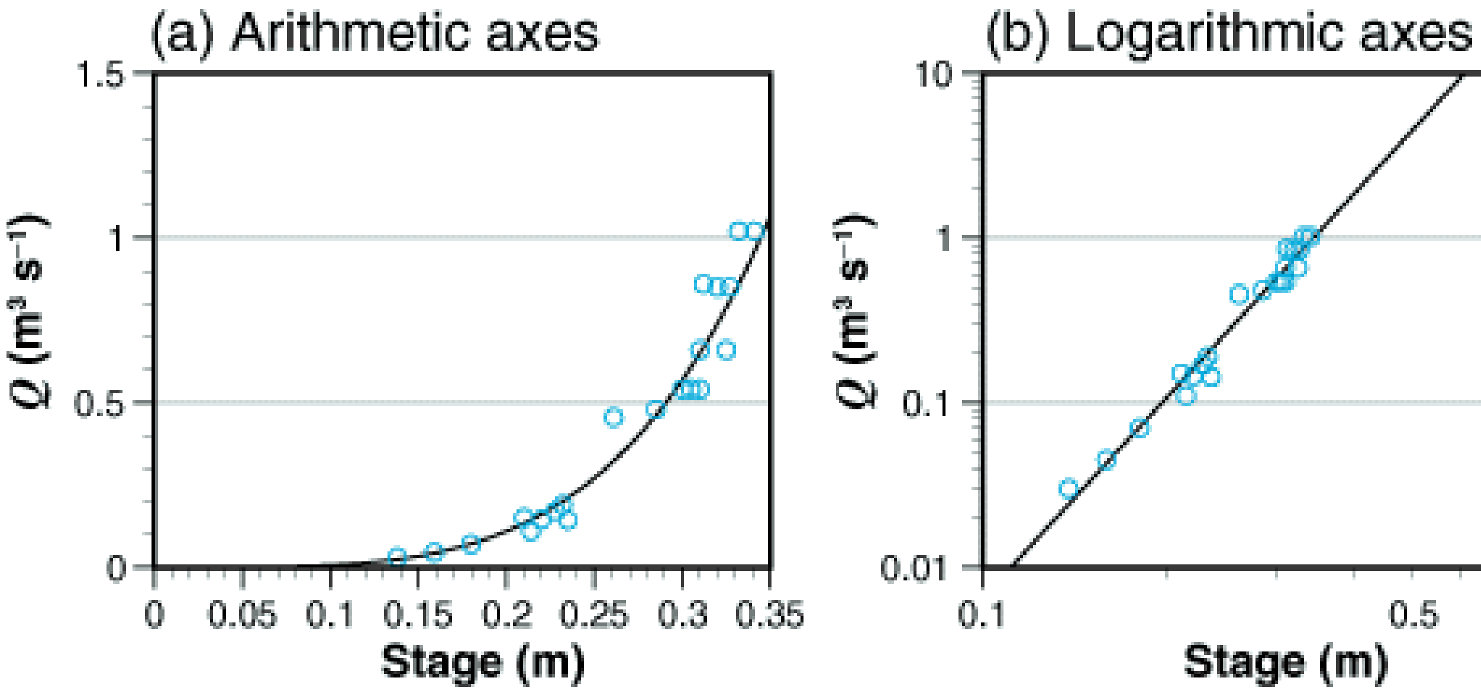


(Hornberger et al., 1998)

Errors using float type water level gauges

Type of sensor	**Range of error (cm)**
Staff gauge	1-3
Float operated gauge	0.2-0.4
Pressure transducer	0.2-1
Bubble gauge	0.5-1.5
Ultrasonic sensor	0.2-1
Peak level indicator	5-10

Creating a rating curve



(Hornberger et al., 1998)

How to obtain continuous discharge [m^3 s^{-1}]?

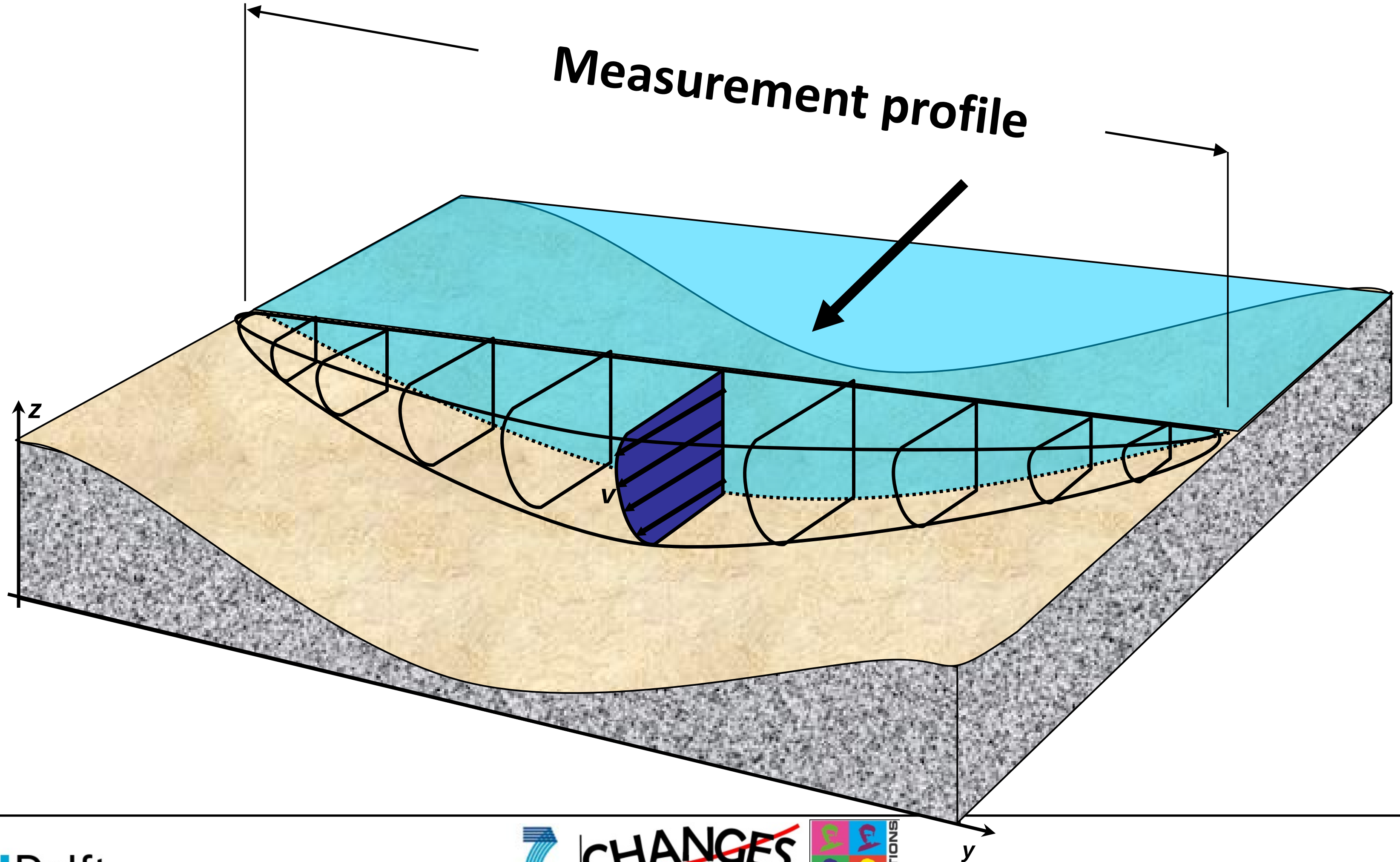
Measurement of discharge at different stages

Dreisam, 257 km^2

Q ≈ 0.05 [m^3 s^{-1}]

Q ≈ 150 [m^3 s^{-1}]

Velocity- and profile measurements

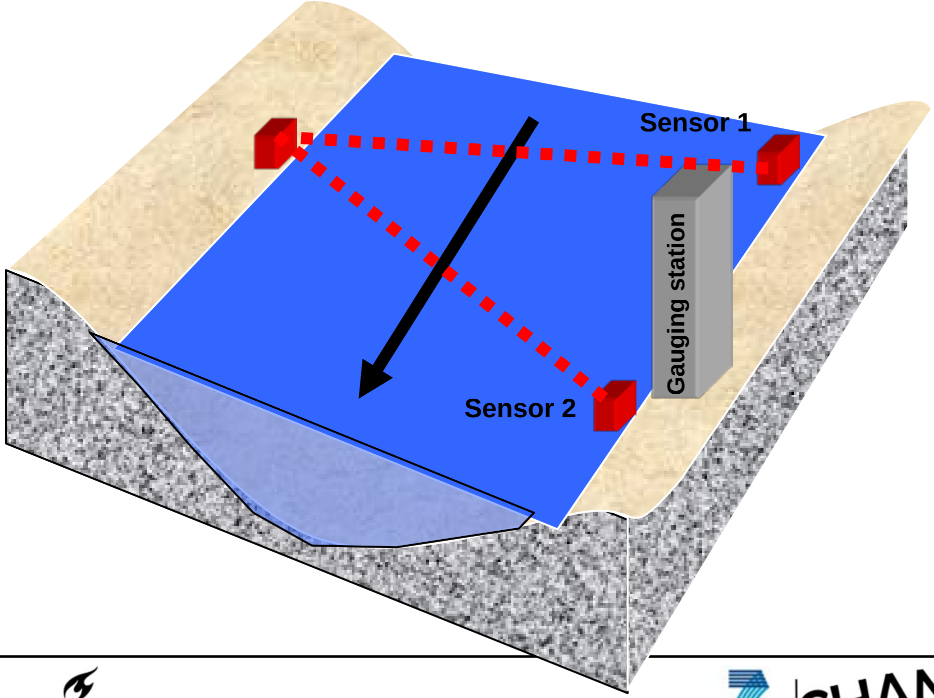


Ultrasonic discharge measurement

Measurement in fresh and waste water

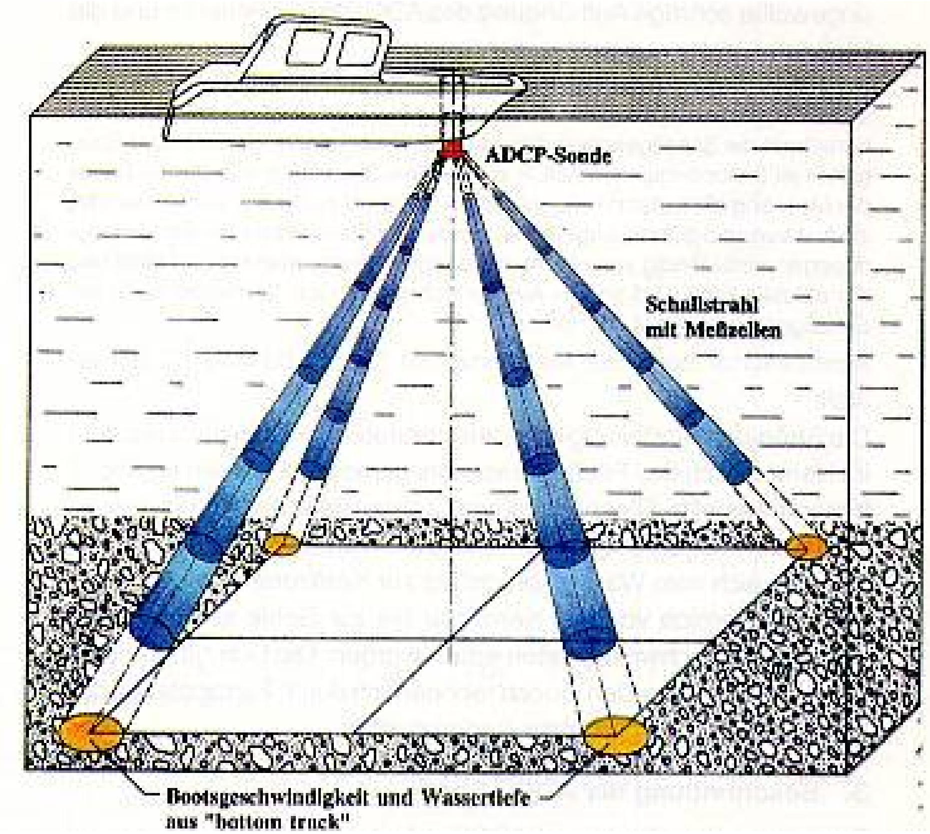
based on transit-time or Doppler method (acoustic signal propagates faster in flow direction)

Problem with high sediment loads (flood event)



(www.quantum-hydrometrie.de)

Acoustic Doppler Current Profiler (ADCP)



www.wsa-fr.wsv.de

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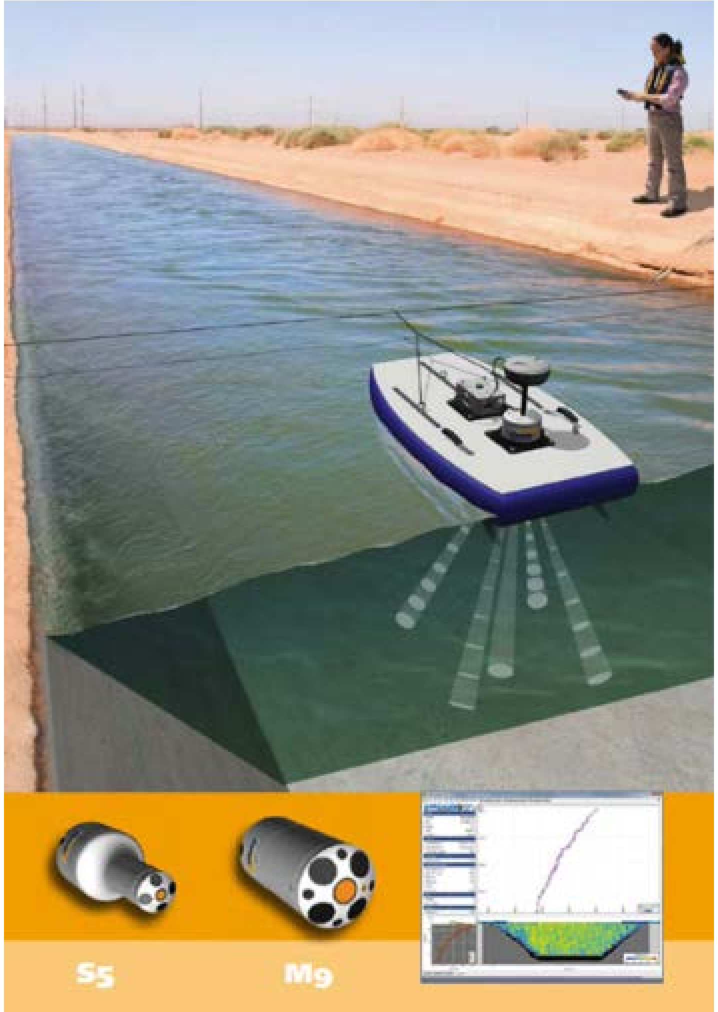


Acoustic scanning of the water body

Reflection of acoustic signals at suspended particles

Measurements is different depths possible

Problems at extreme high sediments loads

Q-h-relationships and its maintenance

- Measurements in a distance of min. 10% of the total range of possible discharge values.
- 2-4 measurements each year to confirm the rating curve
- Requirement: steady-state conditions. Flood waves (non-stationary) will lead to hysteresis effects.


UNESCO-IHE, Migina catchment, Rwanda

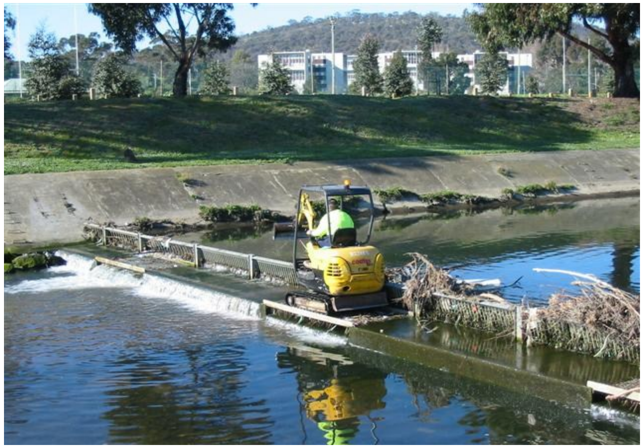
Occurrence of floods: logistic problems

- Communication lines destroyed
- The pen of the recorder stopped, or the housing of the water level recorder submerged by the flood
- The reservoir of the raingauge overtopped, or the raingauge washed away by the flood
- The rating weir completely destroyed by the flood
- The bridge on which the recorder was installed blocked by debris
- While trying to measure the velocity, the current meter was caught by debris and lost

Occurrence of floods

Occurrence of floods

Occurrence of floods



Occurrence of floods

Flood surveys

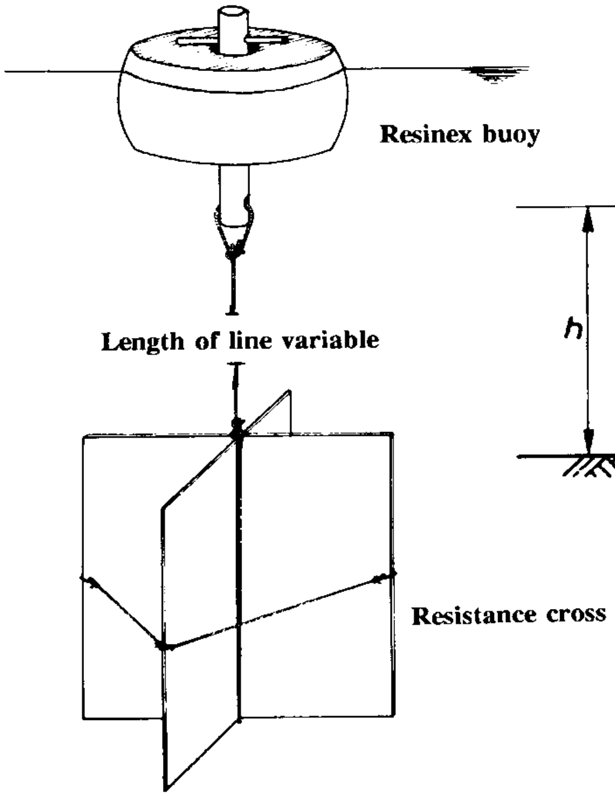
- discharge measurement using floats
- flood mark survey
- Peak level indicators
- slope area method
- simplified slope area method
- interviews

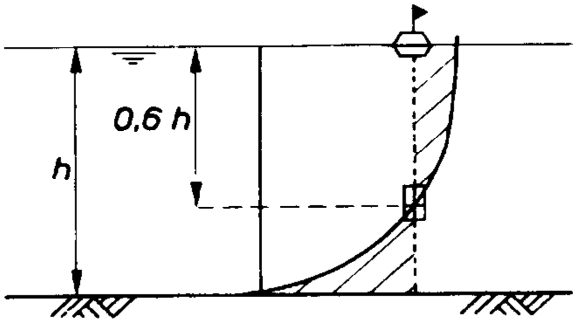
} during flood (discharge measurement using floats)

} morning after (flood mark survey; Peak level indicators; slope area method; simplified slope area method)

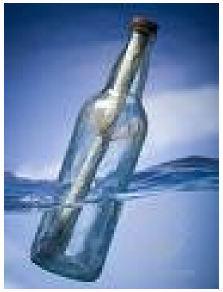
} historic floods (interviews)

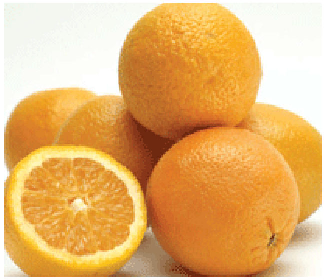
Flood surveys: floats





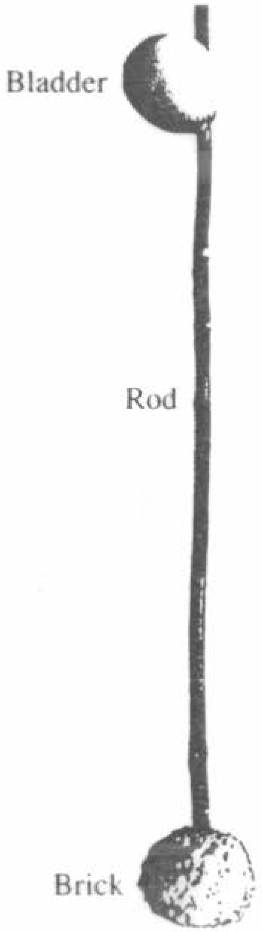
Flood surveys: floats





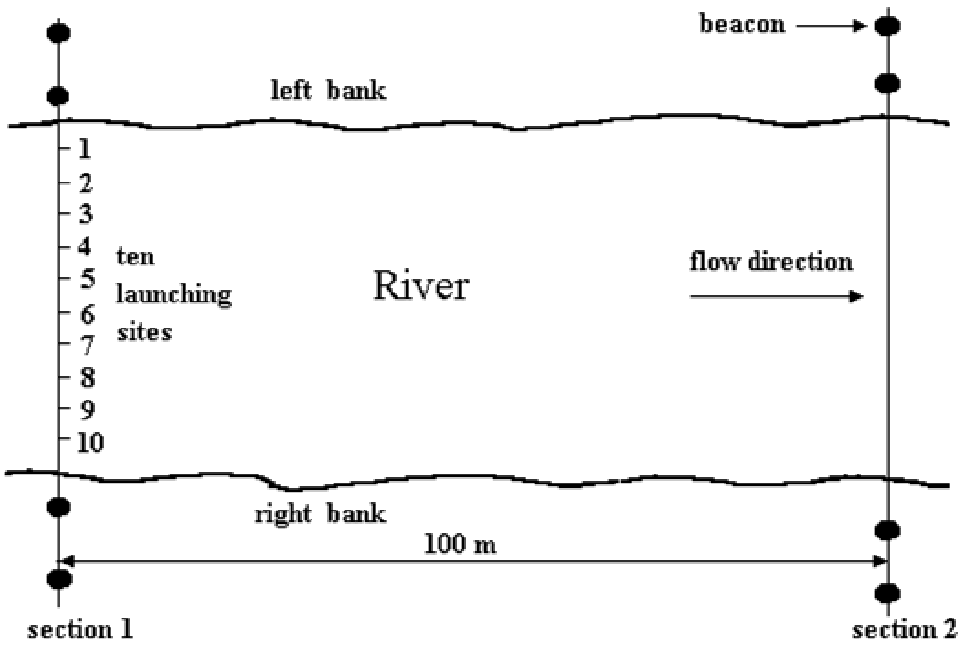
Cheap floats

Flood surveys: float measurements

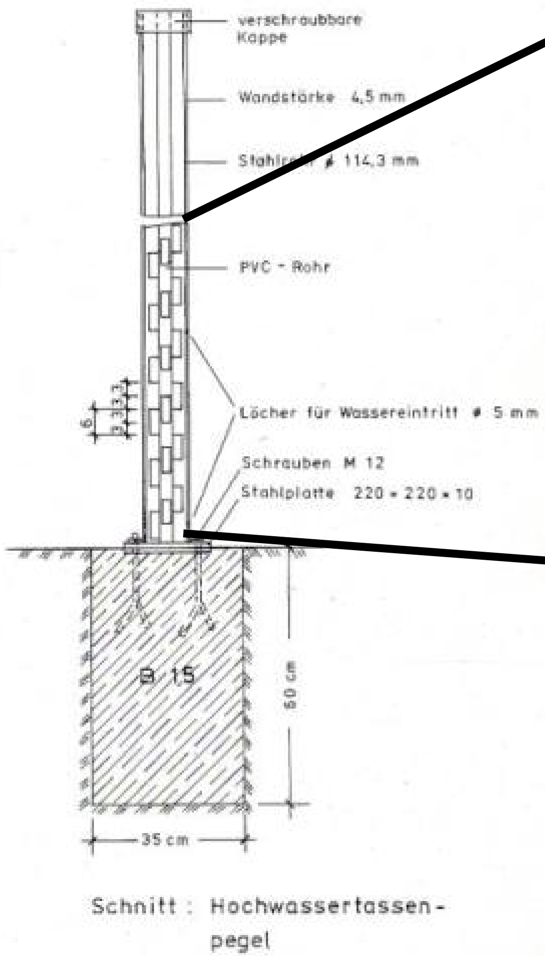


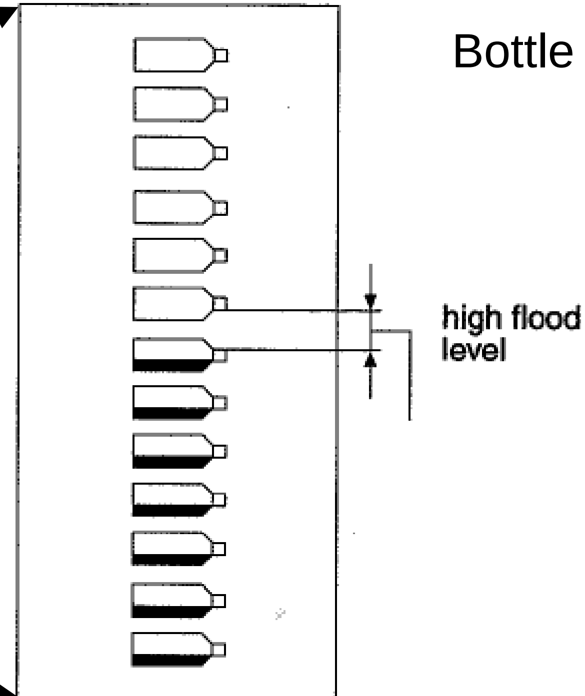
Flood surveys: advantages

- longitudinal integration
- correct vertical position
- quick survey technique
- floats are cheap
- easy to improvise
- debris no problem



Peak level indicators





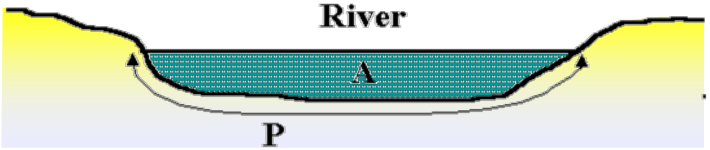
Bottle gauge

Flood surveys

Flood surveys – slope area methods

$$Q = C\,A\,\sqrt{R}\sqrt{S} = C\,K\,\sqrt{S}$$

$$K = \frac{\sum\left(A_i\sqrt{R_i}\right)}{N}$$



A = cross-sectional area
P = wetted perimeter
R = A/P = hydraulic radius

Q = discharge [m^3/s]

C = Chezy's coefficient [$m^{0.5}/s$]

A = cross-sectional area [m^2]

R = hydraulic radius [m]

S = longitudinal slope

K = geometric conveyance [$m^{2,5}$]

Flood survey – simplified slope area method

$$\log Q = 0.188 + 1.33\log A + 0.05\log S - 0.056(\log S)^2$$

Riggs (1976)

$$A = \frac{\sum A_i}{N}$$

Q = discharge [m^3/s]

A = cross-sectional area [m^2]

S = longitudinal slope

N = number of sections

Thanks for your attention!